(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: **0 162 410 A2**

(12) **EUROPEAN PATENT APPLICATION**

(21) Application number: 85105948.5

(22) Date of filing: 17.03.82

(51) Int. Cl.⁴: **B 23 P 11/02**

(43) Date of publication of application: 27.11.85 Bulletin 85/48

(84) Designated Contracting States: DE FR GB NL SE

(60) Publication number of the earlier application in accordance with Art. 76 EPC: 0 089 379

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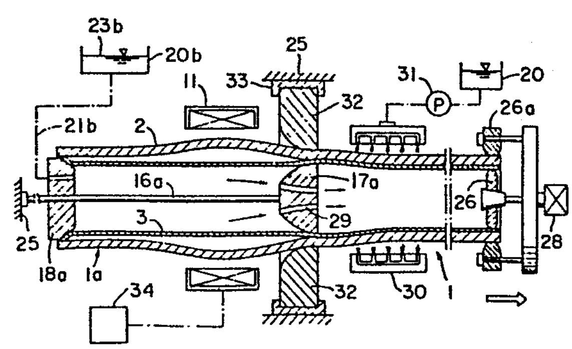
(54) **Method of producing multiple-wall, composite tubular structures.**

(57) In the method of producing a double-wall composite tube by the steps of 1) applying heat to an outer tube (2), and 2) applying expanding pressure to an inner tube (3) inserted into the outer tube (2) so that the inner tube (3) expands in diameter into tight contact with the outer tube, at least one of the steps 1) and 2) is carried out with respect to a local zone of the tubes 2) and 3) which travels progressively from one end to the other of the tubes thereby to cause the outer tube (3) to sucessively expand locally in the travelling local zone and the inner tube (2) to undergo deformation in expansion to fit tightly against the outer tube (2), and the expanding pressure acting on the inner tube (3) is thereafter removed, the two tubes being left to attain the ambient temperature, whereby a tight interference fit is obtained therebetween. Radially-inward constrictive pressure is applied to the outer surface of the outer tube (2) which has been heated in said travelling local zone a die (32) which encircles the outer tube (2) and travels progressively from one end to the other end of the outer tube. Expansion pressure is applied to the inner tube (3) mechanically by mandrel (17a) which is drawn forcibly through the inner tube (3) from one end to the other end.

FIG. I



EP 0 162 410 A2

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This invention relates generally to the production of composite metal tubes having laminated multiple walls and used for piping in chemical and other plants, as oil and gas well tubings, for oil and gas pipelines, and like pipes.

Among the multiple-wall composite tubes of the character referred to above and known heretofore for transporting fluids such as those containing corrosive substances, there are double-wall pipes in each of which the inner pipe or liner tube is made of a corrosion-resistant material for effective conducting of corrosive fluid, while the outer pipe is designed to provide strength to withstand internal pressures and external forces. For example, there is a double-wall pipe comprising a stainless-steel inner pipe and a carbon-steel outer pipe in which the inner pipe is fitted.

Among the known methods of producing such composite pipes, the shrink-fit method and other tube heating and expanding methods have been developed. In these methods, in general, the inner pipe is inserted into the outer pipe and expanded while the outer pipe is heated, the outer pipe thereafter being cooled and shrunk thereby to obtain a tight or interference fit between the two pipes.

In a known tube heating and expanding method, (EP-A-00 15 712) a considerably large-scale heating device comprising a large number of heating elements or the like must be provided on the outer side of the outer tube, whereby the required equipment becomes disadvantageously large and expensive. Another difficulty arises in the case of tubes of long length in that the weight of the apparatus and equipment becomes great, whereby the operation and maintenance thereof become troublesome.

Still another problem encountered in the prior art is the possibility of cracking, implosion, and the like occurring in multiple-wall composite tubes during use because of insufficient degree of interference fit between the constituent tubes.

Furthermore, there has been a lack in the prior art of an efficient, accurate, and economical apparatus for producing multiple-wall composite walls of excellent characteristics as are afforded by the method of this invention.

It is an object of this invention to provide a method of producing multiple-wall, composite tubular structures in which method the above described difficulties encountered in the practice of the prior art are overcome.

According to this invention, briefly summarised, there is provided a method of producing multiple-wall composite tubes, wherein an inner tube is inserted into an outer tube, and radially-outward expansion pressure is applied to the inner tube so as to expand the same plastically into tight contact with the outer tube, and wherein heat is applied from the outside to the outer tube by heating means so as to establish a locally heated zone of the outer tube substantially around the circumference thereof, the locally heated zone being caused to travel from one end to the other end of the outer tube, and tubes are thereafter permitted to obtain ambient temperature, characterized in that radially-inward constrictive pressure is applied to the outer surface of the outer tube which has been heated in said travelling local zone and successively expanded in diameter in said zone, said constrictive pressure being applied by a die which encircles the outer surface of the outer tube and travels progressively from one end to the other end of the outer tube, following said travelling local zone, to cause the outer tube to undergo plastic deformation in radial constriction, and that the radially-outward expansion pressure is applied to the inner tube mechanically by a mandrel which is drawn forcibly through the inner tube from one end to the other end of the same in substantially the same transverse plane as said die and which causes the inner tube to fit tightly against the outer tube backed up by said die.

The nature, utility, and further features of this invention will be more clearly apparent from the following detailed description with respect to preferred embodiments of the invention when read in conjunction with the accompanying drawings, in which:

FIGS. 1 and 2 are side views respectively indicating modes of practice of the method of the invention, in each of which a die is used in conjunction with a mandrel.

In an embodiment of this invention as illustrated in FIGS. 1 and 2, a die 32 for acting on the outer surface of an outer tube 2 is used in addition to a mandrel 17a for operating cooperatively therewith. In the example shown in FIG. 1, an inner tube 3 is closed at its two ends, filled with cooling water and caused to shrink in diameter, and inserted into an outer tube 2 of large diameter at atmospheric temperature thereby to form tentatively a composite tube, and the cooling water is then drained out of the inner tube 3.

Then, into one end of the inner tube 3 in the composite tube 1a prepared in this manner, a mandrel 17a of a diameter greater by a specific amount than the inner diameter of the inner tube 3 is forcibly inserted. At the same time, a die 32 is forcibly pressed onto the outer tube 2. The mandrel 17a is fixed by way of a connecting rod 16a to a stationary frame part 25, while the die 32 is fixed to a stationary frame part 25 by way of a bracket 33.

In front of the die 32, an annular induction heating device 11 connected to a control device 34 is installed to encircle the outer tube 2. At the same time, a cooling device 30 supplied with cooling water from a cooling water source 20 by way of a pump 31 is provided behind the die 32 to encircle the outer tube 2.

Furthermore, a seal clamp device 26, 26a is attached to the rear end of the tubes and is coupled to a drawing device 28 such as a pinion-and-rack mechanism. Tap water 23b is supplied from a tap water source 20b through a flexible conduit 21b and a seal cap 18a, through which the above mentioned rod 16a is passed in a sealing state, to fill the interior of the inner tube 3, which is thereby cooled.

The mandrel 17a is provided with through passage holes 29 for free passage of the tap water from the front side to the rear side of the mandrel within the inner tube 3.

Then, when the drawing device 28 is operated to draw the composite tube 1a toward the right as viewed in FIG. 1, the inner tube 2 at its region acted upon by the mandrel 17a is mechanically expanded by it, since the mandrel and the die 32 are fixed in position, and yields to undergo plastic deformation along a stress-strain curve. On the other hand, the outer tube 2, which has been heated and expanded in diameter by the heating device 11 in front of the die 32, is subjected to a mechanical confining force by the die and is integrally fitted onto the inner tube 3. The outer tube 2 is then immediately cooled and shrunk by the cooling water from the cooling device 30, while the inner tube 2 is relieved of the expanding force and, in a tightly fitted state with the outer tube 2, is drawn rearward.

By this operation wherein the composite tube 1a is drawn in this manner as it is heated, worked mechanically, and cooled, a tightly joined double-wall tube 1 is finally obtained. After the entire composite tube has been thus processed, the seal cap 18a is removed to discharge the water 23b out of the composite tube 1, which is then drawn away from the mandrel 17a and the die 32. By being removed from the seal clamp device 26, 26a the composite tube is exposed to the atmosphere, and the outer tube is cooled to the atmospheric temperature, whereby its shrinking in diameter is promoted. On the other hand, the inner tube 3 is no longer cooled by the water 23b, and its temperature therefore rises to the atmospheric temperature, whereby its increase in diameter is promoted. As a result of these two additive effects, an even greater interference fit is obtained, and a double-wall tube of tubes in a strongly joined state is finally produced.

In the above described example, the double-wall composite tube is produced by drawing the tube past the mandrel, die, and heating and cooling devices. In a modification of this mode of practice, as shown in FIG. 2, the heating device 11, the mandrel 17a, the die 32, and the cooling device 30 are coupled by way of rods 16b to a forward drawing device 28a, while the composite tube 1a sealed at its ends by seal caps 18a and 18b and filled with water 23b is fixed to a stationary frame part 25 by a clamp device 26b. Thus, the die 32 and the mandrel 17a, as well as the heating device 11 and the cooling device 30, are caused to travel relative to the composite tube 1a. The operational effectiveness of this arrangement is substantially the same as that of the preceding example.

It will be apparent that various modifications of the above described two examples are possible within the scope of this invention. For example, the entire front part of the outer tube may be heated; the heating device may be of the steam heated type; and the cooling water within the inner tube may be forced-fed cooling water.

According to the above described modes of practice of the invention as illustrated in FIGS. 1 and 2, the inner tube inserted into the outer tube by a measure such as cooling is filled with cooling water, and a mandrel is placed in contact in a tube expanding state against the inner surface of the inner tube, while a die is placed in a confining or squeezing state against the outer surface of the outer tube, whereby fundamentally, the inner tube is mechanically expanded while the outer tube is mechanically constricted. As a result, the two effects have an additive effect of producing an interference fit between the inner and outer tubes as they are moved relative to the mandrel and the die.

Furthermore, since the inner tube is cooled, and the outer tube before passing by the die is heated and expanded, the outer tube at the time of passing by the mandrel and die is forcibly shrunk prior to the cooling and shrinking after this passing by and is tightly fitted against the inner tube of expanded diameter. The outer tube is thus subjected to the three shrinking steps of constriction by the die, forcible cooling and shrinking, and shrinking due to natural cooling. These effects combined with the increase in diameter of the inner tube due to natural temperature rise after plastic deformation thereof result in a very strong interference fit between the tubes.

Another advantageous feature of this mode of practice of the invention is that, since it is necessary to heat only one portion of the outer tube during the production of long lengths of the composite tube, the heating means and measure are relatively simple. Moreover, tap water is sufficient for cooling the inner tube. Accordingly, the simple apparatus suffices, and the production costs can be kept low. The invention can also be applied to the production of composite tubes formed from more than two tubes.

K 22664 S8/D-ma May 14, 1985

Claims:

1. A method of producing multiple-wall composite tubes, wherein an inner tube (3) is inserted into an outer tube (2), and radially-outward expansion pressure is applied to the inner tube (3) so as to expand the same plastically into tight contact with the outer tube (2), and wherein heat is applied from the outside to the outer tube (2) by heating means (11) so as to establish a locally heated zone of the outer tube substantially around the circumference thereof, the locally heated zone being caused to travel from one end to the other end of the outer tube (2), and tubes are thereafter permitted to obtain ambient temperature,

characterized in that radially-inward constrictive pressure is applied to the outer surface of the outer tube (2) which has been heated in said travelling local zone and successively expanded in diameter in said zone, said constrictive pressure being applied by a die (32) which encircles the outer surface of the outer tube (2) and travels progressively from one end to the other end of the outer tube, following said travelling local zone, to cause the outer tube to undergo plastic deformation in radial constriction, and that the radially-outward expansion pressure is applied to the inner tube (3) mechanically by a mandrel (17a) which is drawn forcibly through the inner tube (3) from one end to the other end of the same in substantially the same transverse plane as said die (32) and which causes the inner tube (3) to fit tightly against the outer tube (2) backed up by said die (32).

2. A method of producing multiple-wall composite tubes according to claim 1, wherein the heating means (11), the die (32) and mandrel (17a) are stationary, and the outer and inner tubes (2, 3) are moved relative to said stationary members.

3. A method of producing multiple-wall composite tubes according to claim 1, wherein the outer and inner tubes (2, 3) are stationary, and the heating means (11), the die (32) and the mandrel (17a) are moved relative to the outer and inner tubes.

4. A method of producing multiple-wall composite tubes according to claim 1, wherein the outer tube (2) is cooled after the outer tube has been applied with the radially-inward constrictive pressure by said die (32), the outer tube (2) being cooled in a second local zone traveling in synchronism with the mandrel (17a).

5. A method of producing multiple-wall composite tubes according to claim 4, wherein the second local zone is produced by liquid at low temperature supplied onto the outer surface of the outer tube (2) from cooling means (30) encircling the outer tube at a position rear to the die (32) with respect to the direction of relative travel thereof.

6. A method of producing multiple-wall composite tubes according to claim 1, wherein the inner tube is cooled.

7. A method of producing multiple-wall composite tubes according to claim 6, wherein the inner tube (3) is cooled by supplying liquid at low temperature into the inner tube.

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FIG. 1

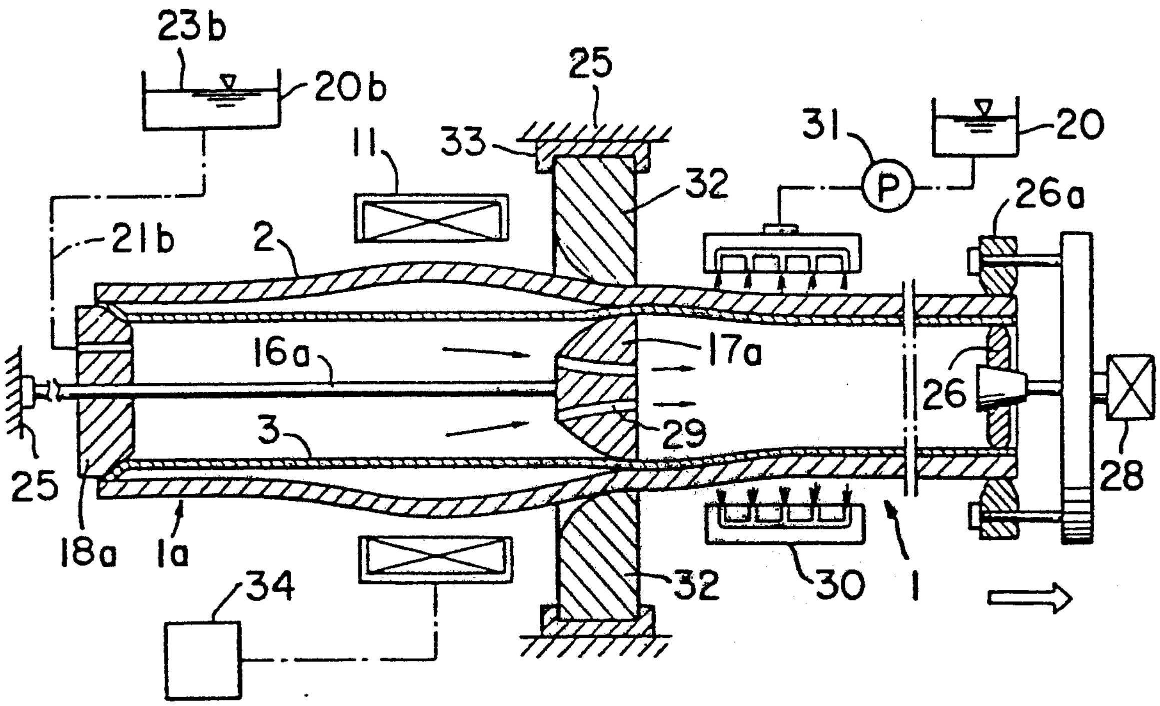

FIG. 2